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WALNUT PRODUCTION IN CALIFORNIA[1]

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THE PERSIAN WALNUT (*Juglans regia*), commonly known as the English walnut, is grown in nearly every county in the state of California. The center of walnut production, however, has persistently moved northward during the past two decades. The following eight counties produced more than two thirds of the state's crops in 1943 and 1944, and are mentioned in the approximate order of their importance: Ventura, San Joaquin, Contra Costa, Santa Clara, Los Angeles, Tulare, Stanislaus, and Riverside.

In the state about 126,000 acres of walnut trees produce annually 55,000 to 65,000 tons of orchard-run nuts. There is a marked fluctuation in production from year to year. The average orchard-run production of the four-year period, 1915 to 1918, inclusive, was approximately 20,000 tons; the average during 1931 to 1934, inclusive, was 37,150 tons.

Importations of foreign walnuts to this country increased up through the year 1924. A marked decrease occurred in succeeding years, the importations ceasing entirely during World War II. This drop was due to import duties, to economic conditions, to an increasing preference for the domestic walnut, and to a domestic surplus which accumulated during the years 1930 to 1940. During the period 1939 to 1944, approximately 91 per cent of the entire crop produced in the United States was grown in California.

A walnut orchard may be expected to bear commercial crops by the time the trees are six to ten years old, according to the variety, the number of trees per acre, and such conditions as soil fertility, irrigation practice, and climate.

The profitable life of a walnut orchard cannot be determined from experiences in California. With good soil, favorable climatic and water conditions, walnut trees will produce satisfactory crops for a long period. Orchards sixty years old are among the most productive in the state.

CLIMATIC LIMITATIONS

The chief climatic limitations of the walnuts are frosts in spring and fall, extreme heat in summer, and insufficient winter chilling.

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Frost Injury.—Frosty areas should be avoided for walnuts. Spring frosts below 30° F will injure catkins, new growth, and young nuts. Late-blooming varieties are less subject to injury from the spring frosts than the earlier-blooming types. When frosts occur as late as May, the late-blooming varieties may suffer more injury, since the nuts (½ inch or more in diameter) of the early-blooming varieties will stand lower temperatures at this time than the blossoms of the late varieties.

Young twig growth is subject to injury by early fall frosts. The injury may not be apparent until spring, when the tree fails to leaf out on the injured part of the past season's growth. Dormant trees are seldom injured by winter temperatures occurring in California walnut districts.

The French varieties Mayette and Franquette have grown without severe injury where the minimum winter temperature occasionally reaches 0° F.

Heat Injury.—Temperatures above 100° F, accompanied by low humidity, cause walnuts to sunburn if they are exposed to the direct rays of the sun. In the inland valleys this temperature, or higher, often occurs during the summer months. Sunburned nuts usually become "blanks" if the injury occurs during June or July. If the sunburning occurs when the nuts are more fully developed but not mature, the kernel may become partially shriveled. High temperatures cause a large percentage of the kernels to darken in color. A sunburned hull may stick to the shell or stain it, causing the nut to be a cull.

Winter Chilling Requirements.—In spring seasons following very warm winters, especially in warm coastal locations of southern California, walnuts will be delayed in starting growth. In such years, walnuts produced on shoots growing from buds which start growth very late will be undersized, and the total crop sometimes will be materially reduced. Most French varieties, such as the Franquette and Mayette, have a greater winter chilling requirement than the Santa Barbara soft-shell types. These French varieties are not suited to southern California conditions, although they are satisfactory in central and northern California where winters are cooler.

SOIL REQUIREMENTS

Depth and Character of Soil.—Successful walnut culture is dependent upon favorable soil conditions. A well-drained silt loam soil at least 5 to 6 feet deep, containing abundant organic matter, free from a high or fluctuating water table, and free from alkali, is ideal. There are moderately successful orchards on fine silt soil underlain with sand within 4 to 5 feet of the surface, but such properties require skill in management. Coarse sandy soils, heavy adobe soils, and clay loams underlain by adobe are not well suited to walnut orchards.

Drainage and Alkali Injury.—Most of the high water tables in arid regions carry more or less alkali in solution. The mere presence of a water table within 9 or 10 feet of the surface is usually only part of the difficulty—the alkali being of greater concern—for the deep-rooted trees obtain a portion of their moisture from this water table, and may be injured by the salts in it, even though there is a seemingly sufficient layer of good soil above the water table.

It is difficult to place a safe boundary beyond which injury from a high water table is not likely to occur. As much depends upon the nature of the water as upon the actual depth below the surface of the ground. The success of

walnut culture on land with a high water table is influenced by the rainfall, irrigation practice, nature of the soil, and quality of the irrigation water. Orchards severely injured by an alkali water table have improved to some degree after the installation of drains.

Quality of Irrigation Water Used.—The quality of irrigation water for walnuts is important. Relatively small amounts of alkali salts in the water are harmful to walnut trees. Of all the orchard crops in California, walnuts seem to be one of the most sensitive to alkali injury. In districts of heavy rainfall and on well-drained soils, water of poor quality may be used with less harm to trees than in the more arid regions, or on soils which are poorly drained.

The kind of salts contained in the water bear as greatly upon the injury as do the type of soil and the other conditions of the orchard. Even a small amount of boron in the irrigation water causes marginal leaf scorch and sometimes severe defoliation, with consequent lowering of quality and yields. Any new water supply should be analyzed, and an expert opinion given regarding its suitability for walnut culture.

When common salt is the predominating toxic material, injury is apparent during the latter part of the summer or early fall. The point of the leaf and margins, and finally most of the leaf surface turn brown, causing a premature leaf drop. Severe injury causes the leaves to drop as early as August. This may result in an abnormal leafing out and blossoming in late summer or fall.

Rainfall.—The amount of rainfall is a good indication of the amount of irrigation water necessary to supplement it. Other factors, such as frequency, duration, amount of individual rains, runoff, and season of occurrence, must also be considered, since they influence the proportion of the total precipitation which penetrates into the root zone of the walnut trees.

In many areas the rainfall is not sufficient to wet the soil to a depth of 6 feet even when no covercrop is grown. Some districts receive enough to grow a good covercrop, but the soil is dry by late winter. A few areas receive enough rainfall to wet the soil to a depth of 6 feet and also to support a winter covercrop. Winter irrigation is advised in those areas where rainfall will not supply the soil moisture needed to produce a covercrop and penetrate to a depth of 6 feet.

VARIETIES

History.—The original walnut plantings in California were the hard-shell type of seedling trees, few of which remain.

In 1867, near Santa Barbara, Joseph Sexton planted part of a sack of walnuts which were probably imported from Chile. The resultant trees produced both hard-shell and paper-shell types of nuts. Second-generation trees from nuts of this planting produced the Santa Barbara soft-shell. The walnut industry in southern California developed from seedlings grown from the best Santa Barbara soft-shell trees. In southern California, practically all varieties (except the Payne and Eureka) are descendants of the original Sexton planting. Such varieties include the Placentia, Pride of Ventura, Neff, Prolific, Wasson, Ehrhardt, and Chase.

Many of the varieties of walnuts grown in France were imported into northern California about 1870 by Felix Gillet. The Franquette, one of the most valuable varieties grown in France, has become the leading variety of central

California. The Mayette is also another imported French variety. A seedling from the Gillet nursery produced the original Concord tree in Contra Costa County. The Payne variety, a seedling, probably traces its heritage to the French importations.

New varieties which would combine the best individual characters of present varieties and be better adapted to special climatic conditions are needed. A number of promising seedlings are being tested now. Individuals contemplating new plantings should discuss the variety situation in their districts with local representatives of the College of Agriculture, packing-house managers, and experienced growers.

Choice of a Variety.—The varieties chosen for planting should be those which experience has shown to produce the highest yields and best quality of nuts. New varieties of the future should be a decided improvement upon the present varieties; otherwise they are not worthy of propagation.

It is essential to have nuts with a strong, well-sealed shell to withstand handling in packing and shipping without cracking. The proportion of kernel to the total weight of the nut in the leading varieties varies between 40 and 50 per cent.

No one walnut variety is suited for planting throughout the whole state. The success or failure of a variety depends upon its adaptation to its surroundings.

Placentia.—The Placentia is one of the favorite varieties in southern California. The young trees grow rapidly, are precocious yielders, and have a tendency to bear good crops annually. In some areas, however, the nuts blight badly. Another defect of the Placentia is its tendency to spring open at the apex if dried too rapidly. The nuts are of desirable size. They have a fairly smooth shell and usually are oval, though they tend to vary in shape, some strains being nearly round and somewhat roughened. The shell is thin, but strong. The kernel is smooth, plump, and light colored, and is taken as a standard of quality and appearance for the Budded grade of nuts. The kernel quality is usually poorer in the interior valleys of southern California than in the coastal areas. The Placentia is not satisfactory in central or northern California.

Eureka.—The Eureka tree grows vigorously but comes into bearing at a later age than the Placentia or the Payne. It blooms rather late and generally escapes injury by spring frosts. The nuts ripen three weeks later than those of the Placentia. The Eureka is distinguished from other varieties by its pronounced elongation, rather straight, parallel sides, slightly rounding to square ends. Its chief defect is a condition known as "shrivel tip" of the kernels. This trouble is especially severe in the inland districts.

Blackmer.—This variety is also known as: Mautner, Westfall, Westphal, Meridian, Leib and Leib Special, Vaughn's Pride, and Money Maker. The Blackmer so closely resembles the Eureka that they are often packed together.

Ehrhardt.—The Ehrhardt walnut is a Santa Barbara soft-shell type, closely resembling the Placentia. It is somewhat rougher, slightly larger, and better sealed.

Wasson.—The Wasson is medium sized and rather rough; the shell firm and well sealed. It is a Santa Barbara soft-shell type and bears relatively large crops. The Wasson is adapted to the same sections as the Placentia.

Pride of Ventura.—The Pride of Ventura is a selected type of Santa Barbara soft-shell seedling and is grown in southern California. Its alternate bearing habit is its main defect. The nuts are large and fairly smooth, the shell is heavy and well sealed. The kernel quality is superior to that of the Placentia.

Franquette.—The Franquette blooms about four weeks later than the Payne and later than the Eureka. Thus it escapes injury by spring frosts. It is slow to reach full bearing.

The nut is elongated, pointed, and moderately rough. The shell is very well sealed, and fairly well filled with a light-colored kernel. The Franquette is recommended for central and northern California.

Although the true Franquette is a distinct clonal variety which originated in France, it has been propagated in California partly from seedlings. Here the name Franquette now includes a group of similar strains or varieties marketed as Franquette but varying in habits of growth, yields, etc. Some strains are very slow in coming into bearing and are poor yielders. Therefore, when planting Franquette nursery trees or topworking to Franquette, it is very desirable to be sure that the scions or budwood come from trees of a strain which bears good crops of high quality in the district.

Mayette.—The name Mayette, as used in California, includes a large group of somewhat similar strains or varieties. The trees are large and spreading and start spring growth about two weeks before the Franquette. The strains may be further classified as the round type, such as the San Jose Mayette, the round, hard-shell type, such as the Triple X, and the long type, such as the Tribble. In most Mayettes the meat is relatively small in proportion to the size of the shell, but the color is good. The San Jose Mayette is very poorly sealed and requires packing in cartons. The Triple X has a heavy shell and is well sealed but has not yielded consistently large crops. It holds its catkins very late and is sometimes used as a pollinizer for the Franquette. Another strain, the Tribble, yields high in some districts and is well sealed. Mayettes are grown only in central and northern California.

Hartley.—This is a seedling of French parentage, selected by John Hartley of Napa, which has been propagated widely in central and northern California during the past ten years. In tree habit it resembles the Mayette but is a weaker grower than the usual Mayette. The nuts are longer and more pointed than most Mayettes. Quality is high and sizes are good. The trees come into bearing very early and produce large crops under favorable growing conditions.

Payne.—The parent seedling tree of the Payne variety was discovered by G. P. Payne, near Campbell, California. This variety is now grown in most walnut areas. Its early and heavy bearing are its chief desirable characteristics. The Payne tree, because of its very heavy production as a young tree, makes a slow growth. The nuts are borne prominently on the outside of the trees and are subject to sunburning. The shell is of medium thickness, somewhat pitted, and well sealed; the kernel is full, with moderate convolutions, and of good quality.

The Payne is a desirable variety to interplant in a Franquette orchard, and for such use it may be of great value. Thus, during the first ten or twelve years of the growth of the orchard, the total production will be more than doubled.

After this period the Paynes should be removed because the Franquette trees will require all of the space.

The Payne is notoriously subject to blight and, until satisfactory control measures are known, cannot be recommended as a permanent tree in those areas where blight is regularly prevalent and severe.

Concord.—The Concord tree is vigorous and an annual producer of medium-sized crops. The shell is rather smooth; the nuts are round type and well sealed; the kernel is fairly plump, medium light colored, and of good quality. This variety is not recommended for planting except in central coast counties. Its kernel quality is extremely poor in the inland valleys.

ROOTSTOCKS

Northern California Black Walnut.—The choice of rootstocks for the walnut has narrowed down to a preference for the northern California black walnut because it makes a good graft union and has certain other advantages. This species is resistant to some degree to the oak root fungus (armillaria root rot). It is apparently resistant to the common root-knot nematode, *Heterodera marioni* (Cornu), and the nematode *Cacopaurus pestis*, but is sometimes injured by the meadow nematode, *Pratylenchus pratensis* (de Man).

The greatest disadvantage of the northern California black walnut as a rootstock is its susceptibility to crown rot. The matter is further complicated by the fact that the northern California black walnut is often confused with the southern California black walnut, which is especially susceptible to both crown rot and root rot and is therefore not recommended as a rootstock. Plantings of both species occur in southern and northern California. The fact that the seed came from northern California has not always been an assurance that the northern species was obtained.

Hybrid Rootstocks.—The Paradox-hybrid rootstock, which is a cross between the English and any of the black walnuts, makes a rapid-growing tree. Such trees have not been produced in any large quantity in the past, and because of the difficulties in propagating hybrids it seems probable that their use in the future will be restricted to areas where the added vigor of the hybrid is of especial importance.

The Royal-hybrid walnut is a cross between the eastern black walnut and either one or the other of the California black walnuts. Its use as a rootstock is limited by the difficulty in producing the hybrid seed stock.

Persian Walnut Seedlings.—The Persian walnut seedling grown from especially vigorous trees, such as a hard-shell variety, is a good rootstock wherever oak root fungus or alkali soil is not a consideration. These seedlings have the advantage of making a smooth graft union free from any constriction. They are also apparently much more resistant, under orchard conditions, to crown rot and to root rot. These two characteristics of the Persian walnut have been the principal reason for its popularity in several of the districts of southern California. The Persian walnut stock is more subject to injury by the common root-knot nematode than is the northern California black. In one district Persian seedling trees are being killed apparently by the nematode *Cacopaurus pestis*. The slow initial growth of the Persian stock is objectionable to the nurseryman.

NURSERY PRACTICE

Walnut trees can be propagated in the nursery either by grafting or budding. Most southern California nurserymen prefer grafting, whereas in northern California budding is the usual practice. High budding gives a short section of black walnut trunk. This decreases danger of sunburn and prevents entrance of oak root fungus into the Persian trunk at the ground line.

Grafting.—One year after planting the nuts, the seedlings should be 1 inch or more in diameter at the surface of the ground. The surface soil is hoed away from the crown of the trees to a depth of 2 to 3 inches, and the scion is inserted in the stock just below the level of the ground. After the scion is tied and thoroughly waxed, the soil is hoed back, covering the scion to a depth of 1 to 2 inches.

The grafted trees are grown one year in the nursery and trained to a whip-like growth free from lateral branches. Each tree must be tied to a stake approximately 1×2 inches $\times$ 8 feet.

Budding.—When walnuts are propagated by budding, the nuts are given an early start and the seedlings are kept growing rapidly until August. At this season they are large enough to receive a bud near the surface of the ground. Patch budding is the method most commonly followed, although shield budding may be successfully used if the chip of wood is carefully removed from the bud. The bud should be ripened by removing the leaf, leaving the petiole attached to the base of the bud for a period of about 10 days before cutting. After the bud is inserted in the stock, it is firmly tied in place by means of waxed cloth. Ties on buds applied during the growing season must be loosened at about 10-day intervals or at least often enough to prevent severe constriction. Late summer or fall buds are allowed to remain dormant until the following spring.

Requirements for Good Nursery Trees.—Grafted trees sell according to size, with a premium placed upon the larger trees. A medium-sized tree (8 to 10 feet) may be preferable to either an extremely large, or a very small tree. A very large tree may be injured considerably in the process of digging it from the nursery plot; a small one may be stunted, with a poor root system, and may never make a first-class orchard tree.

STARTING THE YOUNG ORCHARD

Arrangement of the Orchard.—Walnut trees are spaced so as to permit the planting of 12 to 27 per acre in mature orchards, the number depending on variety and growing conditions. Mature orchards grown under favorable conditions with trees 60 feet apart each way are among the most productive in the state. With this spacing, individual trees have room to develop fully. A large proportion of the nuts are produced on the side branches, and the trees maintain a healthy growth of new fruiting wood for many years.

In close plantings—trees 30 to 40 feet apart—the side branches are shaded, the fruit spurs on the lower branches die, and the crop is borne mainly in the tops. Plantings, 30 to 40 feet apart, should be thinned out by removing every other diagonal row (fig. 1). The remaining trees will then stand approximately 42 to 56 feet apart.

One of the most favored systems is to plant the orchard 30 by 30 feet. The trees may be all of one variety, or of two, planted alternately. With the latter method, there is the advantage of the choice between two varieties when the time arrives for removing half of the trees. If this method is carried out, nearly twice the tonnage may be expected during the first ten or fourteen years than if only the permanent trees are planted. Orchard thinning is usually started when the trees are from ten to fourteen years old, the time varying according to tree size. Trees should not be left until they crowd excessively, as illustrated in figure 2.

Fig. 1.—An old seedling orchard thinned out by removing every other diagonal row. (From Bul. 379.)

Care of Trees before Planting.—If the trees are received from the nursery before the ground is ready for planting, they should be unpacked and heeled in where they will be shaded. The soil around the roots should be thoroughly watered after they are heeled in. If it is more practical, the trees, with the roots packed in damp sawdust or shavings, may be held for a time under a shed.

Planting Nursery Trees.—Walnut trees should be planted during January or February so that the soil may be thoroughly settled around the roots and growth may start with the beginning of the normal growing season. Holes should be dug deep enough to allow room for the full length of the taproot, which may be from 18 to 30 inches. The lateral roots may be 6 to 8 inches long, and the hole should be wide enough to accommodate them.

In filling in the soil around the roots, the topsoil should be used. It should be tamped thoroughly without bruising the roots. The young trees should be irrigated as soon as they are planted.

Planting the Orchard with Black Walnut Trees, and Topworking.—The practice of topworking black walnut trees planted in place is common in central and northern California. Its justification is based on a greater percentage of survival and superior vigor of black seedlings as compared with Persian

walnut trees propagated in nurseries under the somewhat unfavorable conditions that often occur in hot interior valleys, unirrigated mountain districts, or when intercrops are grown close to the trees. Young black walnuts can better withstand water shortages and competition from intercrops and weeds; they also are more resistant to sunburn and borer attacks. Topworking in the orchard requires considerable skill and consistent follow-up care.

The planting of one-year-old black walnut trees is preferred to the method of planting the black walnut seed in place, although both methods are used. The nursery-grown black seedlings are more easily cared for and usually give

Fig. 2.—A typical example of crowded trees, being spaced 40 feet. They are producing walnuts only in the tops, and some trees will soon have to be removed in order to obtain a satisfactory yield per acre. (From Bul. 332.)

a more uniform stand. Only vigorous trees should be planted. There is evidently no disadvantage in cutting the taproot since a better branched root system may result.

When the black walnuts are established by planting the nuts in the field, two to four walnuts are planted in each place where a tree is to grow. Later the smaller trees are pulled out, leaving the most vigorous.

Black walnut seedlings are usually large enough to bud during the second summer or to graft the following winter. Topworking when the trees are young decreases the need of propping and tying. Trees can be topworked at a single point on the trunk, or buds or grafts can be placed in side branches. The latter method gives a tree with multiple unions and main crotches of black walnut wood. Such trees are somewhat stronger and less likely to split, although single-union trees are generally satisfactory if main limbs are properly spaced on the trunk.

Where budding is practiced the patch bud is most commonly used. Budding can be done whenever the bark on the black walnuts "slips" well and suitable buds are available. Budding is usually done in summer (July–August) and spring (April–May). Spring buds are forced into growth by cutting back the

stocks as soon as the buds are established. Summer buds are left dormant until the following spring.

Grafting is done in late winter or early spring. Best success is usually obtained when grafts are placed just after growth starts on the stocks. Methods depend on the size of stock to be topworked and the experience of the operator. Side grafts and whip grafts are best for small branches, those of ¾ to 1 inch diameter. Bark, cleft, or saw-kerf grafts are better for stubs 3 to 5 inches in diameter. To decrease danger of serious heart-rot infections, it is desirable to graft large trees high enough so that stubs are not larger than about 4 to 6

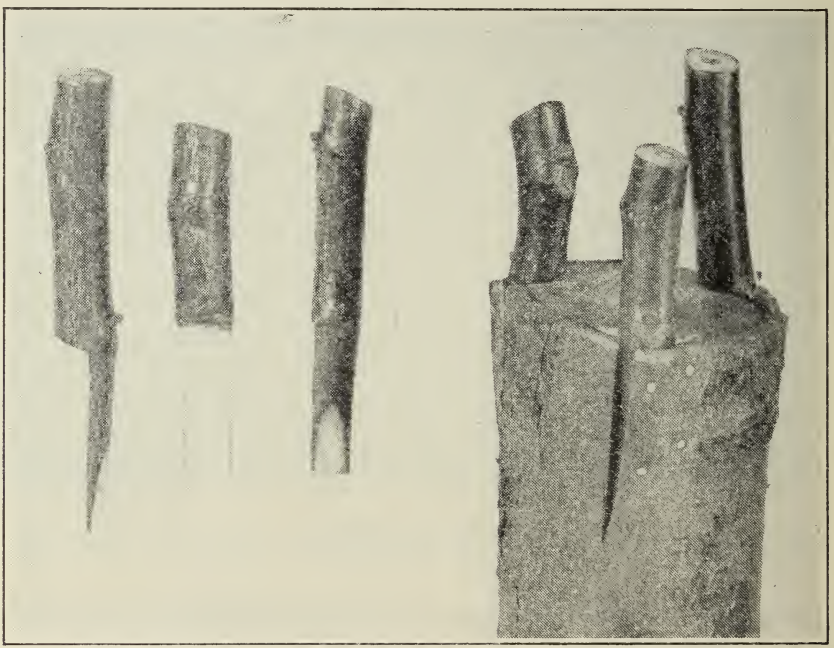

Fig. 3.—Bark grafting, showing typical scions, with method of inserting them in the stock and holding them secure by small nails.

inches in diameter. Bark-grafting methods illustrated by figure 3 are generally the most successful although other methods are sometimes used by highly skilled workers.

Whatever method of grafting is practiced, waxing to prevent drying out is one of the most important details. All cut surfaces and bark cracks of the stock and scion should be covered with grafting wax as soon as the scions have been tied or nailed in place. Frequent inspections and rewaxing to keep all cracks covered are essential. Water emulsified asphalt compounds make a satisfactory grafting wax and can be used cold. If grafts are tied in with strings, these should be cut 3 weeks or more after growth starts, before they tighten enough to restrict growth. Covering grafts with punctured paper bags seems desirable.

Whatever method of topworking is practiced, bracing and tying of the new growth, as illustrated by figure 4, is usually necessary to prevent breakage during the first and second years. It is not advisable to let the growth go be-

Fig. 4.—Supports in place on which to tie growing scions on top-worked trees during the first year. (From Bul. 379.)

yond 12 or 15 inches before the supports are put in place and the first tying is done. Additional ties should be placed as needed throughout the first growing season.

All water sprouts from the stock starting within 6 to 10 inches of the scions or buds should be removed completely at frequent intervals during the first spring and summer to prevent excessive competition. In cool to intermediate districts water sprouts farther down on the limbs or trunk can be removed completely before they reach 6 inches in length. In hot districts they can be slashed back to about 6 inches whenever they reach a length of about 1 foot. They should not be allowed to grow to considerable size and then removed completely, especially in hot interior districts, until the new top is well established. Complete removal during midsummer often results in severe sunburn injury to the trunks.

Training Young Nursery-grown Trees.—Walnut trees come from the nursery as one-year-old whips. In cool coastal areas where sunburn can be prevented easily by whitewashing or by using tree protectors, the trees are usually headed from 5 to 6 feet above the ground at planting time. Here, buds can be rubbed off the lower part of the trunk, or growth from them removed as soon as it starts. In this way, higher buds will be forced into growth to form part of the main framework of the tree.

In hot interior districts, where danger of trunk sunburn is more serious, trees can be cut back more severely at planting, with only 5 to 7 buds left above the rootstock union (usually 18 inches). This forces the low buds into growth, which will protect more effectively the lower part of the trunk from sunburn. At the time of the first winter pruning the most vigorous upright branch is selected to form the trunk of the future tree and is not cut back. One or two small lower branches on the southwest or south side can be cut back to short stubs and left for one year to aid in sunburn protection. All other branches should be removed. This low heading at planting time should not determine the height of main framework branches. At the end of the first year the most vigorous and upright branch may be selected to take the place of the cut off top and continue the leader form of tree. Other branches should be removed or cut back. If a vase-shaped tree with a high head is wanted, the central branch can be cut back after it has passed a desirable height and lateral buds will then develop into main framework branches.

Trees are usually trained in one of three forms: central leader, modified leader, or vase shape. The advantage of the leader type is primarily in the greater strength of framework, there being many more lateral limbs distributed along a greater space on the main trunk. The laterals should be spaced preferably about 2 feet apart vertically and spiraled around the trunk so that the horizontal angle between adjacent branches is about one third of a circle. A modified leader type is started like a full central leader, but the leader is lost after development of three to six main framework branches. In the vase type there are usually several main framework branches, originating at nearly the same point on the main trunk. This centralizes the strain of supporting the top. Vase-shaped trees, being weak at the crotch, are subject to more breakage. Many vase trees have too many main branches. Not more than three or four are desirable.

Development of central-leader or modified-leader-type trees requires more attention and careful pruning than the more common vase shape. It is a fairly easy process with upright growers like Eureka and Franquette, but difficult with more naturally spreading trees like Placentia, Payne, and Mayette.

Whether the ideal selection is the full central leader, the modified leader, or the open-vase type, the permanent branches to form the framework of the trees should be selected so that they are spaced as far apart as practicable, both vertically and horizontally. Excess branches should be removed at winter pruning time during the first several years, but in interior districts a few small, low branches on the southwest side of the trunk should be stubbed back and left for shade until the top develops sufficiently to protect the trunk.

The first main framework branch should not be lower than 4½–6 feet from the ground. Secondary laterals tend to become horizontal as the trees mature and should not be started lower than 8 feet from the ground, except under unusual conditions of very strong prevailing winds or where certain varieties, such as the Payne, do not make large trees.

It should be remembered that several years are usually required to develop a satisfactory framework. Young walnut trees should be pruned consistently each year with a definite type of framework in mind.

CULTIVATION

Walnut trees are naturally deep-rooted, and the character of surface-soil cultivation is of minor importance compared to the welfare of the tree.

Cultivation of any kind—plowing, disking, harrowing, or any other method of working up the surface soil—is only a means to an end. In itself, cultivation is not a practice essential to the well-being of the walnut orchard.

Purposes of Cultivation.—Cultivation of the soil in a walnut orchard is practiced to achieve the following results:

1. To incorporate into the surface soil covercrops, green manures, fertilizers, and bulky organic matter of any kind.

2. To keep summer weed growth down to a point where the weeds do not compete with the tree for the available supply of soil moisture. The amount required and the cost and supply of irrigation water, as compared with cultivation costs, should be the determining factor in deciding whether clean culture or "weedy culture" is to be followed.

3. To keep the surface soil in such condition as to permit preparation of irrigation furrows, dikes, or basins. Efficient irrigation is largely dependent upon the distribution of irrigation water to where it is needed.

4. To prepare a smooth soil surface so the nuts can be readily seen and harvested efficiently.

5. To prepare a good seed bed for planting the covercrop and to make the land ready for subsequent irrigation.

6. To put the surface soil in a condition to retain a maximum amount of the winter rainfall with a minimum amount of soil erosion.

Injury from Improper Cultivation Practices.—The practice of subsoiling or deep tillage of any kind in walnut orchards is never justified. Repeated cultivation of wet soil will pack it, and form a plowsole which will make water penetration difficult. Excessive cultivation of dry soil also injures its structure.

COVERCROPPING

Covercrops may be grown to improve the physical texture of the soil and thus increase the rate of water penetration. Covercrops are also important to prevent soil erosion in orchards planted on even moderately sloping land. Legume covercrops may add nitrogen to an impoverished soil but the amount of nitrogen added will not always obviate the necessity of adding fertilizer. The water-holding capacity of the surface soil is at best only temporarily affected by the addition of reasonable amounts of organic matter.

Organic Content of Soil.—The increase in the organic content of the soil due to covercropping is exceedingly small and temporary. First, the amount of

Fig. 5—A covercrop of melilotus clover (*Melilotus indica*) ready to plow under in late March. (From Bul. 332.)

material actually added is small in proportion to the weight of an acre-foot of soil; and secondly, the rapid loss by decomposition is constantly reducing the amount present. The decomposition of the organic matter is of greater importance than its accumulation.

Partly grown, immature plants contain a larger percentage of nitrogen than plants which are mature. The more mature a covercrop is before being incorporated in the soil, the longer the period necessary for it to decompose because of the relatively lower nitrogen content as growth progresses. A covercrop, when allowed to mature fully and actually go to seed before it is worked into the soil, is usually a real setback to a walnut orchard.

Many cases have been observed where a misuse of covercropping has apparently done much more harm than good. This, however, should in no way discourage the proper use of a covercrop.

Covercrop Management.—Plants suitable for covercropping purposes and amount of seed to sow per acre are shown below:

Crop	Pounds per acre
Melilotus clover	20
Purple vetch	40
Mustard	5–10

Such legume crops as vetch or melilotus clover (also commonly called bitter or sour clover) make a relatively slow growth (fig. 5) and should be planted as soon after walnut harvesting as possible. Crops like mustard and rape grow more rapidly in the winter season and may produce a relatively heavy tonnage in only 90 to 100 days. In order to secure a good growth of mustard covercrop, it will be necessary in many orchards to fertilize with a nitrogenous fertilizer.

Water Requirements of a Covercrop.—One of the important factors in growing a covercrop is water. In districts of low rainfall, one or more irrigations may be necessary to replace the water used by the covercrop.

Climatic and seasonal conditions, as well as the length of the growing period, have a direct effect upon the total amount of water a covercrop will use.

IRRIGATION

Good irrigation practice consists in replacing with as little loss as possible that moisture which is removed from the soil by growing plants. With this definition to work from, it becomes apparent that to follow a satisfactory irrigation program for walnuts, some knowledge is required as to when, from what part of the soil, and in what amounts the trees take water. The relation of quality and quantity of crop produced and responses in tree growth to the irrigation practice must also be considered, as well as the relations of soil type and climate to the amount and frequency of irrigation.

Factors in Irrigation Practice.—In a discussion of the use of water by walnut trees, consideration should be given to the following: (1) total seasonal use, (2) use during different periods of growth, (3) apparent root distribution, (4) relation of soil type to frequency and amount of irrigation water, and (5) effect of insufficient irrigation on tree growth and size and quality of nuts produced.

Field tests indicate that climatic factors and size of trees affect the total seasonal water requirements. Medium-sized trees grown in a climatic area typical of the warm interior sections, use approximately the same amount of water as large mature trees in the cool coastal belt. Orchards in an interior section require annually nearly twice as much water as do trees of the same size and age in the coastal area. Trees in the intermediate area use about 30 per cent more water than trees of a similar size and age in the coastal area. These variations are attributed to differences in both summer temperature and humidity. Approximately one half of the total seasonal water requirement occurs in the months of July and August.

To irrigate a walnut orchard properly, it is not enough to know merely the total seasonal use of water by the trees. The probable root distribution has a definite bearing upon the irrigation program. The normal distribution of walnut roots under various soil conditions has been determined by irrigation studies which have traced the loss of soil moisture at different depths. Many observations lead to the belief that soil-moisture control to a depth of 9 feet is sufficient to maintain a walnut orchard in good condition. Approximately 80 per cent of the soil moisture used by the tree to a depth of 9 feet during the growing season is taken from the upper 6 feet of the soil.

In heavier soils a greater proportion of the water withdrawal from the upper 6 feet is concentrated in the first 3 feet; in the lighter soils it may be more

nearly equal in the 0–3 and 3–6 foot depths. The variations in soil of the first 6 feet do not, however, seem to affect the water withdrawal from the 6–9 foot depths; regardless of the nature of the surface soils, the 6–9 foot depths seem to account for only about 20 per cent. A sharply stratified surface soil and subsoil, or impervious layers of hardpan or rock, or a shallow water table will limit root activity to less than normal depths.

Fall and Winter Irrigation.—Under interior valley conditions the soil dries out during the harvest period. Unless fall rains are unusually early and heavy, the trees may suffer from water shortage during fall months and fail to mature their wood properly. Tops are then subject to killing back by winter frosts.

Fig. 6.—This system of the dike and check furrow irrigation is used to prevent runoff and obtain an equitable moisture distribution throughout the orchard. (From Bul. 332.)

Therefore, an irrigation is needed immediately following harvest in most years.

When winter rainfall is not sufficient to wet the soil to field capacity to a depth of at least 6 feet, irrigation water should be applied during late winter to make up the deficiency. It may be necessary to hold the water on the land for several days and to obtain deep penetration, as shown in figure 6.

Soil Moisture in Relation to Size and Quality of Nut.—The special value of abundant soil moisture in the early spring is in producing large nuts. Winter irrigation to supplement a low seasonal rainfall may be looked upon as an insurance against winter drought and the resultant small percentage of large nuts. The walnut shells of most of the varieties begin to harden about the middle of June, after which there is little or no increase in size.

The most rapid growth of the nuts takes place during the 5 or 6 weeks immediately after the blossoming period. A shortage of soil moisture in a walnut orchard during the early part of the growing period will result in production of a large percentage of small sizes. No amount of midsummer or late irrigation water will increase the size after the walnut shell hardens.

Winter irrigation, when rainfall is insufficient, supplies moisture for the spring growth of the trees. Small amounts of moisture only are transpired by the dormant trees or lost through soil surface evaporation.

The effect of irrigation practices on quality of the kernels may be summed up as follows: the lack of soil moisture during June, July and August results in poor quality, as measured by the relative plumpness of the kernels.

Irrigation Methods.—On fairly flat lands walnuts are usually irrigated by means of furrows, contour checks, strip checks, square checks, or a combination check and furrow system. The check systems are better adapted to the use of relatively large heads of water. On steep slopes the contour furrow or ordinary furrow system is used.

For a working knowledge of the effective irrigation of a deep-rooted crop like the walnut, it is necessary to sample the soil at various depths. Only by the use of a soil tube or auger can the farmer more than guess the soil-moisture conditions throughout most of the root zone.

A knowledge of the amount of water used is as important as studying its movement through the subsoils. It may prove to be a greater mistake in the end to apply too much water than not to apply enough. This is especially true with stratified soils, or where a water table exists.

The actual method of applying the water to the soil must be adapted to the soil conditions, grade of the land, and other local factors in each case.

INTERCROPPING

Intercropping of young walnut orchards is the general practice. It has usually proved successful in making the land support the orchard before the walnuts come into bearing.

Annual Intercrops.—The intercrop to be grown will depend upon various circumstances. In the bean-growing districts, beans are an ideal intercrop for the young orchard. Beans are often grown in an orchard until the trees are eight to ten years old.

Outside the bean-growing districts, the choice of intercrops depends largely upon the market conditions for the proposed crops. Several of the vegetables commonly used for canning may be grown in the young orchard without harm to the trees. Such crops as tomatoes, peppers, and melons are often used.

Intercrops of corn, milo, squashes, and pumpkins are not generally grown, because of their apparently harmful effect upon the trees. Alfalfa is occasionally used as an intercrop, but is not recommended.

Fruit Trees.—Peaches, prunes, and apricots are among the fruit trees most commonly used in intercropping. In many instances young orchards interplanted with these fruits have made less growth than orchards interplanted with beans. Nevertheless, in many instances, the fruit trees have been profitable and have made the orchard self-supporting while the nut trees were growing. If fruit trees are used as an intercrop, the farmer must consider the irrigation problem carefully to be certain that the needs of the walnut trees can be harmonized with those of the companion crop.

FERTILIZATION

Field trials with various kinds and amounts of fertilizers show that nitrogen fertilizers are essential in most walnut orchards to maintain productivity. There are three sources of nitrogen for walnut trees: (1) the native nitrogen in the soil, (2) the nitrogen furnished by legume covercrops, and (3) the nitrogen added to the soil by manures, hays, or chemical fertilizers.

In most walnut orchards the native nitrogen supply in the soil is either so little, or its conversion into nitrate nitrogen is so slow, that the trees eventually

Fig. 7.—Effect of fertilizer on mustard covercrop: area in foreground not fertilized; that in background received 100 pounds nitrogen per acre.

suffer from nitrogen deficiency. In some instances this may occur before the trees come into bearing. In others, it may not be evident for a long time.

While it is true that legume covercrops do add small amounts of nitrogen to impoverished soils, they do not add enough nitrogen to supply the needs of a producing walnut orchard. Consequently, nitrogen from manures or fertilizers is necessary to make up this deficiency in the soil. The main objections to the use of manures and hays are that they are slow in action and in some districts are relatively costly. Fertilizers, such as nitrate of soda, ammonium sulfate, ammonium nitrate, calcium nitrate, ammonium phosphate, and anhydrous ammonia, are all good sources of nitrogen, and their cost per pound of actual nitrogen is relatively low. In general, the one which provides the most nitrogen for the least money should be used.

A tree affected by extreme nitrogen deficiency has sparse, yellow, and small leaves. There are also many dead twigs in the top of the tree. There are two other characteristics usually prevalent if the trees are receiving inadequate nitrogen. The first is a gradual failure to produce good covercrops, especially

of the nonleguminous varieties, such as mustard. The second is a slow but steady decline in yield. When either or both of these symptoms are apparent, nitrogen should be applied as a trial in part of the orchard.

One of the usual effects of fertilizing walnut orchards is the increase in the growth of covercrops. This is strikingly shown in figure 7; the mustard covercrop in the foreground received no fertilizer, while that in the background was fertilized at the rate of 100 pounds of nitrogen per acre.

The amount of fertilizer which can be used most profitably will vary widely, depending, among other factors, upon the native fertility of the soil, the age of the orchard, and the past farming and fertilizing practice. Where heavy annual covercrops are grown, it has been generally considered profitable to use moderate to heavy applications of 100 or more pounds of nitrogen per acre per year. The advantage of this practice will obviously depend also upon the price of fertilizer and the value of the increased production of nuts.

Zinc Deficiency.—Zinc deficiency, also called "little-leaf," occurs in some orchards on sandy soils in the San Joaquin Valley and interior districts of southern California; there are cases in the Sacramento and Salinas valleys also. For some obscure reason it is often found in spots where corrals were formerly located, regardless of soil type.

In very bad cases there is no normal foliage; only small, yellow leaves are produced, the twigs die back from the tips each year, and the trees are thus badly stunted. In less severe cases trees make good shoot growth in early spring, followed by yellowing and curling of leaves in June and later in the summer. Some good growth may be produced, however, in late summer. Many of the leaves are mottled with light-green patches between veins.

Affected walnut trees respond to a treatment consisting of the insertion of pure zinc or galvanized iron pieces into the sapwood. A glazier's point driver is a satisfactory tool for inserting pure zinc glazier's points into trunks or limbs up to 2 inches in diameter. These points should be driven well into the sapwood, each piece turned parallel with the grain. They should be scattered around, and spaced 1 inch or more apart at the rate of 30 per inch of diameter of limb. For treatment of larger trees, rectangular, galvanized iron pieces about ¾ inch wide and 2 inches long, cut from 22- or 24-gauge material, can be driven into trunks or branches not larger than about 10 inches in diameter. They likewise should be driven well into the sapwood, parallel with the grain, and spaced in rings around the trunk or limb with individual pieces about 2 inches apart, in a staggered pattern. The rings should be about 2 inches apart. Usually at least six rings are needed. This gives a minimum of three pieces for every inch circumference but spaces the pieces about 2 inches apart in all directions. The work can be done at any time of year. Usually one treatment will provide sufficient zinc to keep the trees healthy for several years.

Soil treatments are sometimes satisfactory, but because of variation in the fixing power of different soils, the zinc may become available very slowly; general recommendations of amounts and frequency of application are therefore unreliable. Best results have been secured in very sandy soils with a low fixing power. Zinc sulfate can be placed in a trench about 4 to 6 inches deep and about 2 feet out from the trunk. Amounts to use per tree vary from about 5 to 10 pounds for trees 2 to 8 inches in diameter, to as high as 30 to 50 pounds for

large trees. Material should be applied in early winter. Spray treatments of zinc have not been satisfactory on walnuts.

Deficiencies of Manganese and Copper.—Manganese deficiency is most common in the coastal counties of southern California, but is also found to a limited extent in interior districts of central California. It is characterized by light-green color between the veins of leaves, darkening of a few scattered small leaf veins, and scorching of irregular areas in the leaves between veins and extending to the margin. In severe cases leaves are badly scorched and many drop, beginning in midsummer and increasing in late summer.

Satisfactory results have been secured by spraying with about 5 pounds of manganese sulfate in 100 gallons of water just before the first leaves are fully developed—in May or early June in southern coast counties.

Copper deficiency is found in limited areas in coast range valleys and mountains of central California. Walnuts from affected trees have very badly shriveled kernels. Shoots of the current season develop dark spots in the bark late in the summer; leaves near tips turn yellow and drop, and many shoots die back. Spraying of leaves with bordeaux mixture, 12–6–100, in early summer has given good results in preliminary trials. Soil treatments of 10 to 20 pounds of copper sulfate per tree in trenches 2 feet from the trunk have shown some results, but the effects are subject to variations in soil fixing power for copper.

PRUNING BEARING TREES

Two methods of pruning walnut trees prevail in general practice. In one, the pruning consists merely in the cutting off of the lower limbs that interfere with cultural practice. In the other, the trees are thinned throughout the tops also.

The fact that few walnuts are produced in the centers of the old trees has suggested a moderate thinning out of the branches from year to year in an attempt to promote production more uniformly throughout the trees. Sunlight is necessary for the production and maintenance of fruit spurs, and without some thinning out practically all of the crop is produced on the outside twigs, in the tops, and on the sides of the trees.

In all pruning operations, the limbs should be cut off without leaving any stub. All wounds larger than 3 inches in diameter should be painted with a disinfectant, such as thin bordeaux paste; this should be allowed to dry, then covered with a weatherproof paint, because walnut wood decays rapidly.

Old orchards in which the trees are planted very close together should not be severely pruned to prevent the interference of branches from adjacent trees, but the number of the trees per acre should be reduced, the orchard thus being thinned out. The production in crowded orchards declines prematurely. After three to five years a thinned orchard may be expected to return to normal yields.

Gradual elimination of temporary trees in orchards where trees are beginning to crowd is sometimes desirable. Side branches can be removed from the temporary trees, with one or more central upright limbs left to produce for several years. At least half of the bearing area of the temporary trees should be removed; otherwise, the permanent trees are not likely to receive much benefit. For such pruning, the usual care in making cuts is not necessary.

Satisfactory yields are associated with maintenance of good vigor in mature walnut groves. Average length of growth of at least 8–12 inches on upright shoots over the top of the tree seems desirable in interior districts. In coastal districts possibly 4–6 inches is a desirable minimum. Trees making only 1 to 2 inches of tip growth usually show declining yields. Poor growth and dying of fruit wood are signs of declining vigor, and efforts should be made to determine the cause in each case. In many instances weak trees have responded to applications of nitrogen. Improved irrigation practice has helped where trees needed more water. In some cases lack of vigor has been traceable to such specific causes as accumulation of injurious salts in the soil or attacks of scale insects. In a few orchards detailed fine pruning of fruiting wood has given beneficial results.

WALNUT INSECTS[5]

The codling moth and the walnut aphid, which are widespread in California, are the major insect pests of the walnut. The walnut husk fly is a major pest in several counties, and should it become generally distributed in all the areas where susceptible varieties are growing, it might become more serious than any other pest.

Codling Moth.—This insect passes the winter as a caterpillar, or larva, in a cocoon, in crevices of the bark, in pruning scars, in similar places on the trees, and in debris on the soil or actually in the soil itself. It is also found in drying trays, in dehydraters, and in buildings where walnuts have been temporarily housed, and in burlap sacks used in harvesting. In the spring, the larvae transform into pupae from which adults issue 18 to 30 days later. Emergence is prolonged over a period of from 6 to 8 weeks. The moths are active at dusk and, provided the temperature is approximately 60° F or higher with little or no air movement, females deposit eggs at this time.

The first eggs of the season are laid on the green twigs and leaves, but later they are deposited on the nuts. Upon hatching, the larvae usually burrow into the nut and feed on the kernel. The earlier larvae of the season usually enter through the blossom end, or calyx, causing most of the nuts so infested to drop before reaching maturity. Later, entrance usually is made where nuts in clusters are in contact. When the shell becomes hardened, the larvae cannot penetrate it directly and, hence, must gain entry to the kernel through the fiber at the stem end (fig. 8).

From 35 to 45 days are required for the larva to become fully developed; after this period, it usually leaves the nut and spins a cocoon in some such location as already indicated. In most of the infested localities there is one full generation, a partial second, and sometimes a smaller partial third, according to seasonal climatic conditions. In some areas in northern California there are usually two full generations each year.

The degree of infestation of the codling moth has increased in many sections of the state in the past three decades. Where control measures have not previously been practiced, they should be undertaken when the packing-house records show 2 per cent or more of infestation in a normal-sized crop.

[5] The scientific names and further description of these insects are given in: Essig, E. O., and W. M. Hoskins. Insects and other pests attacking agricultural crops. California Agr. Ext. Cir. 87:1–197. Revised 1944.

The method of control is spraying with basic lead arsenate. Acid or standard lead arsenate has caused injury to the foliage and should not be used. However, investigations are under way in northern California to develop a safe method for its use. The formula for the spray is as follows:

Basic lead arsenate	4 pounds
Deposit builder	1 pint to 1 quart
Water	100 gallons

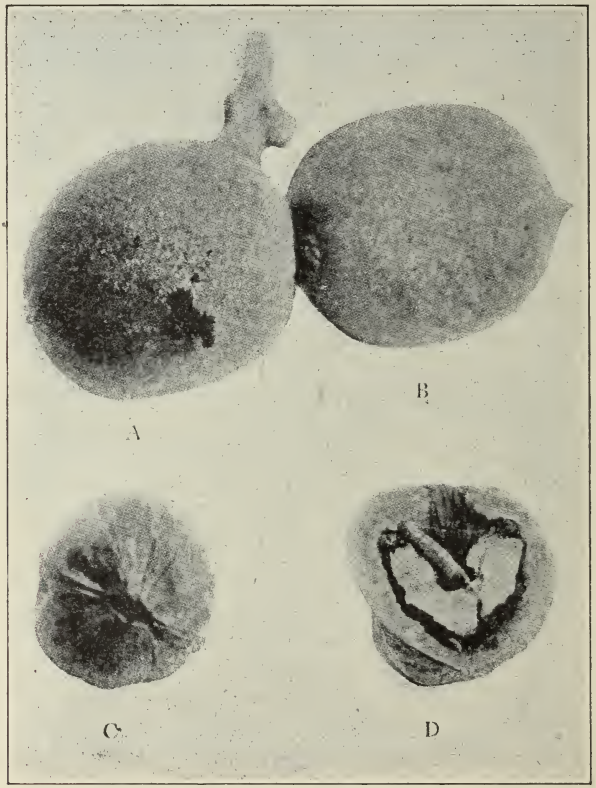

Fig. 8.—*A*, Appearance of green nut after codling moth larva has entered on open side. *B*, Larva usually enters green nut on the stem end as here shown. *C*, A round or oval opening on the stem end of the cured nut is an almost certain sign of infestation. Close examination will usually reveal a certain amount of staining and, frequently, some frass. *D*, Section of walnut showing the codling-moth larva and the damage it has done. (From Bul. 332.)

The spray should be thoroughly applied, covering all of the nuts on the tree, with equipment that will insure good agitation and high pressure (500 to 600 pounds). A tower similar to the one shown in figure 9 should be used when spraying trees 20 feet or more tall. Fifty to 60 gallons may be required for large trees. The time for applications depends principally on moth activity, which may be best determined through the use of bait pans hung in the trees

Pans 8 to 10 inches in diameter, containing the proper fermenting bait, suspended in the upper one third and outer part of the tree attract moths when they are active and depositing eggs. The bait used is as follows:

Malt (Diamalt)	1 pint
Water	19 pints
Yeast (compressed)	1 cake

The bait pans should be put out when the walnuts begin to set, and should be kept in the trees until the majority of the spring brood of moths has emerged. A dozen bait pans, spaced about the orchard, will be sufficient. In

Fig. 9.—Tower spraying for control of codling moth. The platform on which the spraymen are working is 30 feet above the ground. (From Bul. 379.)

most of the infested areas, one spray treatment thoroughly applied and properly timed usually affords satisfactory control. However, in the Stockton area, on Payne walnuts heavily infested, two treatments are apparently necessary for good results.

Walnut Aphid.—The walnut aphid ranks second to the codling moth as a pest. One generation of the aphid succeeds another in the spring and early summer until a heavy population is built up.

Injury is caused by the aphids' feeding in great numbers on the sap of the leaves and giving off honeydew in which a sooty-mold fungus grows. As a result of heavy infestations, many leaves drop during midsummer. Conse-

quently, there is less protection against sunburning of the nuts, and the trees are devitalized. The latter factor reduces the possibilities of a good crop of walnuts the following year. Furthermore, there is an increase in the percentage of perforated shells and shriveled and dark-colored kernels.

Where aphid control is necessary at the time of codling moth treatment, nicotine sulfate at a dosage of ⅓ pint per 100 gallons may be combined with the codling moth spray. In certain seasons, it is necessary to treat for aphids before the codling moth application and again later in the season; treatment is sometimes necessary in districts where the codling moth is not a pest. For such treatment, dusting is recommended as shown in figure 10. Twenty-five to 30 pounds per acre of a 3 to 5 per cent nicotine sulfate dust is used.

Fig. 10.—Dusting to control the walnut aphid.

Walnut Husk Fly.—The walnut husk fly occurs in several thousand acres of walnuts in southern California. The Eureka, Franquette, and Payne varieties are most susceptible to attack. The Placentia, Ehrhardt, Neff varieties, and most seedlings are not usually infested to an important extent except in the oldest infested areas.

The adult flies begin to emerge from the soil late in June or in July and continue over a period of 6 to 8 weeks. The eggs are deposited in the green husks of the nuts, and hatch into maggots which tunnel through and feed upon the inner husk tissue. As a result, a soft decay develops which permanently darkens the shell of the nut. Such affected nuts become culls. The larvae spend about 35 days in the husk, at the end of which time they drop to the soil and burrow to a depth of several inches, where pupation occurs and where they remain until the following year. A few may remain for a period of two to four years before adults emerge.

Cryolite, according to the formulas below, applied as a dust or a spray, is the most satisfactory treatment.

DUST

Cryolite	35 pounds
Petroleum oil (approximately 100 seconds viscosity)	2 pounds
Frianite or talc	63 pounds

For mature trees apply 3 pounds of the dust mixture per tree. This should be applied from two sides and, preferably, at night under quiet air conditions.

SPRAY

Cryolite	3 pounds
Water	100 gallons

For large mature trees, such as the Placentia variety, apply about 30 gallons of the spray mixture.

Two applications are necessary, the first when emergence of adults from the soil is occurring regularly, and the second about 30 days later. Since control on the most susceptible varieties has become more difficult in recent years, the first treatment is applied as a spray and the second as a dust. On less susceptible varieties both treatments are usually applied as dusts. Dust treatment is less expensive than spraying. To insure satisfactory control, treatment should be given to all trees and other interplanted vegetation within the walnut grove, and also to a border zone 50 feet wide of whatever vegetation happens to be present.

Red Spider.—The red spider, or mite, is sporadic in occurrence as a pest on walnuts and is not generally widespread. It occurs more commonly in the dry interior valleys during midsummer and late summer and is usually most severe on trees where soil moisture is deficient.

Dusting with DN dust D8 at the rate of 3 pounds per mature tree is the treatment most commonly employed. Subsequent treatments may be necessary.

Minor Pests.—The following insect pests have periodically infested walnuts, but they are of less economic importance: Catalina cherry moth, walnut blister mite, calico scale, frosted scale, brown apricot scale, Italian pear scale, walnut scale, and California red scale. Among the chewing insects occasionally infesting walnut foliage are the June beetle, the Fuller's rose weevil, and several species of caterpillars. For information on importance and control of these uncommon pests, the farmer should consult the county farm advisor or the local county agricultural commissioner.

DISEASES

Walnut Blight.—The walnut blight is the most destructive disease affecting the walnut crop. The prevalence of this disease varies from year to year, and is usually worse in the coastal districts than in the inland valleys in southern California. The converse of this is true in central and northern California.

Losses are often very severe, especially with early-leafing varieties, in years of prolonged spring rains or fogs which keep the trees wet all day.

Blight is a bacterial disease which attacks the young and tender growth and spreads to the more mature wood, causing the affected areas to turn black and die. Under favorable conditions, the disease is especially destructive to the nuts. It causes them to turn black and drop off when ⅛ to ½ inch in diameter.

It causes full-sized nuts to become blanks, and may make full-grown nuts unmarketable, except as culls, by reason of staining the shell. It shows on the nut as black spots most prevalent at the blossom end, but often scattered over the entire surface.

Studies of the walnut blight organism, methods of carryover and distribution, and control measures are still in progress. Spraying the trees with bordeaux mixture just before the pollination period has given satisfactory control in some districts. In other locations, especially in older groves of less vigorous trees, bordeaux spraying has been discontinued because of injury to the foliage, lowered quality of walnuts, and faster build-up of aphids on sprayed trees. Copper oxide is less injurious to trees and quality of walnuts but seems slightly less effective in controlling the disease. Recent incompleted tests with ammoniated copper carbonate sprays are encouraging.[6]

Melaxuma.—This troublesome disease of the walnut tree has occurred in serious outbreaks. Studies of this disease were carefully made and reported in 1914–15 by Fawcett.[7] The nature and treatment of the trouble may best be summarized by quoting from this author:

> Because of the oozing of dark watery material to the surface of affected areas, this disease is often confused, under the name of "black sap," with sunburn, frost injury, injuries to the bark in cultivation, injury from the decay of wood at places where limbs have been cut off....
>
> The most common location for Melaxuma cankers is at the crotch of the tree where the first limbs join the trunk. The first evidence of the disease is often a black area on the otherwise grayish bark which looks like a dab of tar.... The diseased area later becomes slightly sunken, shrinks and cracks. The "black sap" then oozes out in considerable quantities and stains the bark as it runs down the limb or trunk. The wood underneath is discolored for a short distance and this discoloration usually extends beyond the margin of the killed bark....
>
> Cut out the cankers that have not gone too far on the trunk and larger limbs and disinfect the wounds thus made. The dead and discolored bark should be cut away, getting a little beyond the margin of dead tissue.... Probably one of the best disinfectants to apply to the wound is the Bordeaux paste.... If the canker has practically girdled the limb, the limb had better be cut out.

Crown Gall.—Crown gall, which is caused by a bacterium, is found on many of the deciduous fruit trees. This same organism causes crown gall on walnut trees. The gall is a large overgrowth which usually occurs on the crown and rarely develops higher on the tree. This overgrowth is rough and somewhat spongy, as shown in figure 11, and is not easily confused with the normal overgrowth which often occurs at the bud union of the walnut trees. The galls grow slowly in size and in some cases the trees are girdled after several years.

Galls should be eliminated before they get large. Small galls can be cut out and the wounds, as well as the tools, disinfected. Galls of any size can be treated without skillful surgery, by painting with a mixture of sodium-dinitro-

[6] For further details see: Rudolph, B. A. Bacteriosis (blight) of the English walnut and its control. California Agr. Exp. Sta. Bul. 564: 1–88. 1933. (Out of print.)

Rudolph, B. A. A new blight control spray. Diamond Walnut News 22 (2): 4–6. March, 1940.

Scott, C. E. Walnut blight today. Diamond Walnut News 26 (2): 4, 5. March, 1944.

Ark, P. A., and C. E. Scott. New blight spray proves promising. Diamond Walnut News 27 (2): 10, 11. March, 1945.

[7] From: Fawcett, H. S. Melaxuma of the walnut, *Juglans regia*. California Agr. Exp. Sta. Bul. 261: 129–48. 1915. (Out of print.)

cresolate suspension (Elgetol), 20 per cent, and wood alcohol, 80 per cent, by volume. Most of the hard outer part should first be removed from old galls by knocking it off or roughly cutting it off. The surface to be treated should be clean. Very large galls should not be treated completely at one time because of danger that the tree will absorb too much of the chemical. Inspection, retreatment where needed, and smoothing of the surface to induce more rapid healing over are important. Treatment is not practical if the tree is already almost girdled.

Fig. 11.—A long-standing case of crown gall. The gall usually is inconspicuous on black walnut rootstocks. (From Bul. 379; photograph by C. O. Smith.)

Crown Rot.—Crown rot occurs on the black walnut when used as a rootstock and it usually occurs on trees located in poorly drained soil, or where excessive surface water has periodically collected. The disease involves the bark just below the surface of the ground in the region of the crown, extending frequently a short distance onto the lateral roots. In well-advanced stages, the taproot is killed, caused as often by a girdling effect at or below the crown as by the downward development of the disease.

The first indications of infection—so far as the general appearance of the tree is concerned—are a somewhat stunted appearance of the tree, sparse foliage, lack of twig growth, and a yellowish tint in the foliage. In more advanced cases, the trees appear drought-stricken in midsummer, and the leaves turn yellow and drop off, leaving a crop of nuts exposed to shrivel and later to fall. Such trees usually die the following spring.

The lesion on the crown is characterized by a soft, black, frequently spongy and decayed condition just below the bud union and under the ground. The top margin of the diseased area usually stops at the line of the bud union.

Crown-rot disease ordinarily may be controlled by either of the two following treatments:

1. Complete drying-out of the crown seems to give good control of this disease. Therefore, both as a preventive and cure, all trees on black walnut rootstocks should have the crowns exposed at all times, and irrigation water should never be run closer than 4 feet from the tree crown.[8]

2. After all lesions of any size and depth have been cut out, the wounds are painted with cyanide of mercury (1 part in 500 of water). Then the wounds are painted with a good waterproof paint.

Twig Wilt.—Twig wilt is a serious new disease attacking walnuts in the hotter parts of interior valleys. The disease appears to be caused by a fungus. It attacks the bark and sapwood of twigs and branches, eventually plugging the conductive tissues and causing sudden wilting of leaves beyond the point of attack. Wilting usually occurs during hot periods in the latter part of summer. The dead leaves hang tenaciously on such twigs into the winter, forming characteristic "flags" in the trees. The disease develops slowly in larger branches. Eventually the entire top of the tree is killed.

Control measures so far have been limited to the cutting out of diseased twigs and limbs in an attempt to retard spread of the disease. It is advisable to cut affected limbs a considerable distance below the visibly killed area.

Winter Injury or Dieback.—Winter injury, or dieback, of walnut is characterized by death of the tops of the trees. Such injury is usually first noticeable during the early spring. The most common causes of this type of injury are given below:

1. Early autumn frosts kill the immature, growing shoots. Young walnut trees are especially subject to injury from this cause. Such frosts cause the foliage to die prematurely and in extreme cases kill the ends of the shoots. The small denuded branches are subject to further injury from fall and winter sunburn.

2. Late summer and fall drought causes dieback in either young or bearing walnut groves. Trees experiencing this condition fail to make new growth in the spring, except from the trunks or main limbs. Fall irrigation of the walnut groves has been found to eliminate the injury from drought. The amount of irrigation water to be applied depends upon the type of soil, the amount of soil moisture present at the end of the harvest season, and the length of time remaining before the rainy season normally begins.

HARVESTING AND FARM PREPARATION OF NUTS FOR THE MARKET

Effect of Harvesting Methods on Quality of Crop.—The natural drop of the nuts occurs with most varieties between early September and early November. In actual practice, harvesting is hastened by shaking the trees in order to obtain the highest possible quality. The trees are shaken from 2 to 4 times, the number and vigor of shakings depending upon climatic conditions and variety. In the cooler areas the kernel of the nut matures over a long period of time. The maturity of the kernel and the cracking of the hull occur at about the same

[8] For further details see: Barrett, J. T., and C. O. Smith. Walnut tree crown rot. Diamond Walnut News 8(5):4, 5, 7. December, 1926.

time; because of this, 3 to 4 light shakings are usually desirable in these areas. In the hot interior areas, kernel maturity precedes hull cracking. Thus, in these areas, earlier and more vigorous shaking usually results in better quality. For best quality, walnuts should be gathered, hulled, and dried immediately after shaking.

Nuts left on the ground too long are subject to darkening of the kernels, and may be injured by fog or rain. The effect of rain upon the nuts may be entirely superficial if they are picked up and dried promptly. At best, they will be dirty and more or less stained, causing extra work of washing and making proper bleaching more difficult. The kernels of nuts long on the ground after a rain become moldy and the shells stained on the outside. If the stain is pronounced, it will be impossible to bleach out, and the nuts will become culls.

A certain percentage of nuts will drop with the dried husks adhering. These are "sticktights," and, in their plumpness and in the appearance of their kernels, they are likely to be inferior to the clean nuts. There is usually a high percentage of blanks, and shriveled, moldy, and dark-colored kernels among the sticktight nuts. The percentage of sticktights is greater during seasons of abnormally high temperatures, when the nuts are sunburned and also when the husks are affected with blight. Trees which have suffered drought during the latter part of the growing period, or which are subject to the attacks of aphids or red spiders, or which for any other reason lose their leaves prematurely, produce a high percentage of sticktights and inferior nuts.

A small percentage of nuts will mold after the hulls crack and before the nuts drop from the trees. Sticktight nuts are more likely to be moldy at the time they drop from the trees than those which drop free from their husks. The percentage of moldy nuts will increase if sticktights are left on the ground for a week or 10 days.

The commercial grades are determined by the percentage of edible kernels, the percentage of light-colored kernels, and the appearance of the shell. The effect of harvesting methods upon the color of the kernels can be as pronounced as its effect upon the percentage of moldy nuts.

Early Harvesting and the Use of Mechanical Shakers.—The success of early harvesting methods, rapidly carried out, depends upon the efforts of each farmer in giving the program trial under his own conditions. The program may also be expected to vary with the variety planted and with the climatic conditions in the different walnut-growing districts.

During the past few years there has been a rapid development of mechanical shakers for walnuts, and several hundred shakers are now in use. The shakers are usually attached to tractors; the principles of mechanical shaking are fairly well developed, but designs are not yet standardized.

Substantial savings in labor have been made by use of mechanical shakers as compared with hand shaking. Mechanical shaking is most successful in interior districts where walnuts mature over a shorter period and where more vigorous shaking is required than in coastal areas. The mechanical shakers do a more thorough job, especially on upright limbs of tall trees. Use of mechanical shakers makes early and rapid harvesting more practical in many interior districts, particularly with the Payne, Eureka, Mayette, and Franquette varieties.

Some growers have effected additional savings in labor in harvest operations

by use of special catching devices mounted on wheels, or by catching walnuts on very large sheets of canvas. Cleaners for removal of leaves are used with such equipment.

Careful preparation of the ground by dragging and rolling before harvest makes harvesting easier. Where a large proportion of the crop can be shaken at one time on a smooth ground surface, hand rakes can sometimes be used to advantage by pickers.

Hulling.—When harvest operations are hastened in an attempt to produce high-quality nuts, the frequent shaking of the trees will probably cause a portion of the nuts to fall with the hulls still attached. If discretion is used in shaking the trees, the large majority of the nuts should be in such condition that they can be hulled. Most nuts with cracked hulls can be hulled. Some varieties, such as the Payne, Mayette, and Blackmer, frequently can be hulled by hand or by machine before cracking is visible. Hulling can be done by hand or the nuts can be run through a machine. The latter practice is the quicker and more economical of the two. A machine, however, will not hull nuts which cannot be hulled by hand. It is a labor-saving device only and should be used as such in speeding up the harvest, which, in turn, means a higher-quality crop.

Ethylene Gas[9] *as an Aid to Rapid Harvesting.*—The greatest obstacle to rapid harvesting, once the kernel is mature, is the large amount of green sticktights that fall when the first shaking is done. In some of the interior sections of the state, maturity of the kernel will sometimes precede loosening of the hull by 2 to 3 weeks. The normally warm weather during this period between kernel maturity and hull maturity can and often does result in a greatly lowered quality of the walnut kernel. The green sticktights can be water-sweated to remove the hull but the water-sweating process is not always satisfactory. The use of ethylene gas as a means of loosening the hulls on the green, sticktight walnuts is much more rapid and freer from difficulty than the water-sweating process. The ethylene gassing method has been successful only in warm interior districts of southern California. It is now used to some extent on Placentia and Eureka varieties in these districts. It causes undesirable darkening of veins on the surface of walnut kernels in some coastal districts. The ethylene gas method of treatment is briefly outlined as follows:

1. The kernels must be mature. Immature nuts shrivel badly and are worthless.

2. The trees should be shaken as hard as possible and the green sticktights separated from the nuts that will hull.

3. The green sticktights are placed in a bin which can be made airtight when desired. The bin must be equipped with forced-draft ventilation.

4. Ethylene gas is injected at the rate of 1 cubic foot of ethylene to 1,000 cubic feet of air space (air space is determined on the basis of an empty bin).

5. The temperature in the bin should range between 70° and 80° F. Temperatures lower than 70° slow the process. Temperatures higher than 80° not only slow the process but also tend to darken the kernel.

6. The bin must be ventilated by means of forced draft at least every 12 hours. In some instances more frequent ventilation may be necessary. A sud-

[9] For details see: Sorber, D. G. The use of etbylene in the walnut harvest. Diamond Walnut News 21(5):10, 11, 14. September, 1939.

den rise in temperature within the bin is an indication that the bin should be ventilated. Ventilation may require from 20 minutes to 1½ hours.

7. The bin should be regassed after each ventilation period.

8. Treatment should be continued until 96 to 98 per cent of the nuts will hull readily. This will require from 24 to 72 hours. The greener the hulls, the longer will be the time required for treatment.

Washing.—Immediately after they come through the huller, the nuts must be washed to remove the juice of the crushed hulls, which would otherwise stain the shell and make bleaching impossible. The washing process will not remove the stain on the shells caused by sunburned or blighted hulls.

Washing is done in a large, cylindrical drum made of a coarse wire netting in which the nuts are slowly revolved under a stream of water. They should pass through the drum in a continuous stream so that no individual nut will be in the washer more than 2 or 3 minutes. Nuts which have lain in the mud, even though they dropped to the ground free from the hulls, should also be washed; otherwise, they will be difficult, if not impossible, to bleach.

DEHYDRATION

After walnuts are hulled they must be promptly and thoroughly dried in order to evaporate the excess moisture contained in both kernel and shell. Dehydration will (1) give a product of stable weight, (2) prevent further molding or darkening of kernels, and (3) permit efficient bleaching.

The amount of moisture which must be evaporated varies greatly, but decreases as the harvest season progresses. Adequately dried nuts average 6 per cent moisture, and should not contain in excess of 8 per cent. In recent years the sun-drying of walnuts has been largely superseded by the use of dehydraters. The dehydraters have the following advantages:

1. Dehydraters operate independently of weather conditions, and afford thorough and uniform drying in an average of 24 hours, arrest further molding or darkening of kernels, and minimize the splitting of shells.

2. Labor requirements for dehydration are less than for sun-drying. Automatic heat control permits dehydraters to run with a minimum of attention.

3. Since the peak of demand for walnuts comes in the fall before the normal peak of supply, any operation which speeds delivery of walnuts to the consumer is valuable. Dehydraters afford a steady delivery of walnuts to packing houses for prompt packing and shipping to market.

Principles of Dehydration.—The evaporation of moisture requires the absorption of a definite amount of heat. In dehydration this heat is brought to the walnuts by a continuous stream of air previously heated in a furnace fired by stove oil, natural gas, or butane.

The air conveys heat to the nuts and passes on to absorb and remove the water vapor evaporated by that heat. Natural air currents are neither adequate nor controllable; consequently, fans of the centrifugal, multiblade type are used to blow a large volume of air through the spaces between the walnuts in the bin.

Efficient dehydraters are provided with an air flow of 2,000 to 3,000 cubic feet of air a minute for each ton of walnuts. This air flow requires the expenditure of 1 to 1½ horsepower.

As the air passes through a bin of walnuts, its drying power rapidly decreases because absorption of moisture causes a decrease in temperature and an increase in humidity. Even with vigorous air flow it has been found inadvisable to use a depth of walnuts greater than 2 feet if the air flows in one direction only. Otherwise, the nuts on the intake side will reach dryness while the nuts on the exhaust side are still insufficiently dried.

By periodically reversing the direction of the air flow, the depth of nuts can be increased to about 4 feet. When this is done, all nuts in the bin receive the same average air conditions and consequently dry at uniform rates.

The capacity of any dehydrater in terms of pounds is measured by multiplying the size in cubic feet by 20 pounds, the weight of a cubic foot of dried walnuts.

Walnuts have a critical temperature of 110° F. If heated higher the oil in the kernels will become rancid and make them inedible. Rancidity is not apparent immediately after overheating but requires from a few weeks to several months to develop. One lot of overheated nuts mixed with other lots of normal ones will result in the entire lot's becoming unsalable because the rancid nuts cannot be separated from the good ones. Because of the spoilage caused by overheating, every dehydrater used for walnuts must be equipped with an accurate and dependable thermostat which will automatically prevent the temperature from exceeding 110° F. The use of lower temperatures is not objectionable except that lower temperatures require a longer time for drying.

Selection of a Dehydrater.—Dehydraters can be purchased from one of several reliable manufacturers, or can be built by obtaining plans and specifications from the University of California College of Agriculture. Walnuts can be dried successfully on trays in standard types of air-blast dehydraters, such as are used for fruits or vegetables, provided they are equipped with a special thermostatically controlled heating system which does not permit the temperature to exceed 110° F.

Although the total cost of operation and maintenance of a dehydrater is slightly more than the corresponding cost of sun-drying, the advantages of this modern method of drying counterbalance its slightly greater cost.

Sun-drying.—Sun-drying is accomplished by spreading the nuts in shallow trays with bottoms made of slats spaced about ½ inch apart. The nuts should not be left exposed to the sun during the entire day if the weather is especially dry and hot, for many of the nuts will crack open. If the trays are spread out in the morning and the nuts thoroughly stirred several times, the trays may be piled up when the nuts are still warm.

The trays should be so piled as to allow ventilation between them. At night the nuts should be protected against exposure to fog or dew. The alternate loss and gain in moisture when the nuts are exposed to fog at night and sunshine in the day will cause many to split.

PACKING

Although the packing and selling of walnuts is distinct from their production, each grower should know how they are to be graded and packed in order to realize the importance of delivering high-grade nuts to the packing house.

After being properly cured, the nuts are delivered to the local packing house.

There they first pass under a vacuum hood, which removes the blank or imperfectly filled nuts. From the vacuum, nuts with full kernels pass on to an endless belt where they are hand-culled to remove those which are obviously imperfect.

TABLE 1

A STANDARD OF COSTS FOR WALNUT PRODUCTION IN A MATURE ORCHARD IN CALIFORNIA

Cost item	Cost per acre		
	1934	1941	1942
	dollars	*dollars*	*dollars*
Pruning	1.50	2.66	3.85
Brush disposal	0.90	1.25	1.62
Planting of covercrop	0.30	0.57	0.78
Dusting and spraying	2.00	3.76	5.22
Disease control and surgery	0.90	0.82	1.87
Cultivation, four times, one way	6.00	6.62	7.89
Preparation for irrigation	3.00	2.78	3.41
Irrigation, three or four times	3.60	3.73	4.78
Miscellaneous, bracing, etc.	0.90	1.08	1.38
Cultural labor costs	19.10	23.27	30.80
Tower work, knocking, etc.	4.20	25.06	39.87
Picking 1,500 pounds	13.50		
Hauling out, hulling, and dehydrating	3.60	6.73	11.28
Hauling to packing house	0.75	1.02	1.24
Harvest labor costs	22.05	32.81	52.39
Fertilizer	.....	8.33	10.33
Irrigation water	12.00	9.64	9.75
Covercrop seed	1.00	1.53	1.72
Dust and spray materials	4.00	4.41	4.95
Fuel and power for dehydrating	2.25	2.19	2.22
Miscellaneous	0.25	0.52	0.62
Material costs	19.50	26.62	29.59
General expense, 5 per cent of total labor and material	3.00	3.69	4.95
County taxes on orchard and equipment	15.00	12.11	12.11
Repairs to machinery and equipment	1.00	1.65	2.12
Insurance: compensation and fire	0.75	1.30	1.35
Cash overhead costs	19.75	18.75	20.53
Total cash costs	80.40	101.45	133.31
Depreciation on trees	13.75	13.75	13.75
Depreciation on improvements and equipment	9.00	9.00	9.00
Total cash and depreciation costs	103.15	124.20	156.06
Average farm income from 1,500 pounds per acre	165.00	189.75	217.50
Average profit from 1,500 pounds per acre	61.85	65.55	61.44

The nuts then pass through revolving drums containing a liquid bleach which is harmless to the kernels. Dirt and stains are thus removed and the shells made uniformly bright and clean. The walnuts next pass by on a sorting belt where experienced women pick out the nuts with imperfections that bleaching has revealed. Such nuts include those which are wormy, sunburned, or

moldy. Next the walnuts are mechanically sized into the three standard grades: large, medium, and baby. Since the larger-sized grades bring considerably higher prices, it is obvious that cultural practices, such as cultivation, fertilization, and irrigation, that result in good sizes and grades are most important.

Each size grade is run into large, thoroughly ventilated bins where the nuts remain until the moisture absorbed in bleaching is evaporated. From the drying bins the nuts pass by on a third and final culling belt en route to being packed in bags or cartons. Most of the crop is packed in 100-pound bags for shipment. Since most of the walnuts picked out as culls have good kernels, all such culls go to shelling plants where the edible kernels are recovered and sold as shelled walnuts, while the inedible kernels and shells are converted into various by-products.

SELLING THE CROP

Approximately 85 per cent of the walnut crop is packed and sold for its members by the California Walnut Growers Association, a noncapital, nonprofit, coöperative composed of local associations in all walnut districts of the state. The board of directors of the central association is composed of one representative from each local association. The local associations process and pack the nuts delivered by their members in accordance with the standard established by the directors of the central association. Association members receive the market price of the particular grade of their delivery, less the cost of packing and marketing. Walnut growers who are not association members usually sell their crops to commercial packers.

A STANDARD OF COSTS

Every grower endeavors to obtain as high a profit as possible; hence, he strives to secure a maximum yield of high-quality walnuts, to sell this yield at as high a price as possible, and to secure this production at as low a cost as practicable. Table 1 shows costs during 1934, 1941, and 1942, and is a standard with which a grower may compare his own costs. An economical system of management, similar to that followed by efficient growers, has been assumed in preparing this table; it is shown in enough detail so that growers may use it for comparison with their own conditions. Harvesting costs and all costs per hundredweight are based on a yield of 1,500 pounds per acre. Perhaps some of the costs shown in this table are below average, but they are all within the range shown by growers' records and may well serve as an indication as to whether a grower's costs are unnecessarily high or too low to result in a satisfactory income.

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